2.2 Species composition of algae and cyanobacteria in biological soil crusts on natural substrata

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INTRODUCTION

Many studies have pointed out the biological importance of biological soil crusts (Belnap & Lange 2001). Descriptions of the general biological diversity of biological soil crusts are common in the literature (Johansen 1993). This chapter describes the cyanobacterial and algal populations of biological soil crusts and isolated cultures from sandy loam in Střezovská rokle and wet sand-stone cliffs in the National Park České Švýcarsko.

Microorganisms living on those substrates represent an important component of the ecosystem, serving as the first colonizers of the abiotic substrates. Algal communities may distinctively differ among various localities, depending on the type of substratum or climatic parameters. In tropical ecosystems cyanobacteria generally dominate, while temperate regions are characterized by high proportions of green algae. Finally, accessible humidity and pH of substrata make a great difference for algal composition.

MATERIALS AND METHODS

The biological soil crusts were investigated in a single sampling site in Střezovská rokle and three sampling sites situated in the area of National Park České Švýcarsko. Detailed characteristics of the localities are given in chapter 2.1. Střezovská rokle crust locality consists of eroded Miocene clay sediments. As a result of intense erosion, a gorge in clay bedrock has developed in the cetral part of the reserve. On steep slopes of this gorge in places with regular erosion of sediments, the only biotic cover consists of a biological soil crust that was investigated in this study. The biological soil crusts in České Švýcarsko National Park develop on similarly disturbed microlocalities on bases and slopes of sandstone cliffs with regular erosion hampering the vascular plants succession. In each locality, the samples were taken randomly from the whole biological soil crust by scraping of the substratum with a sterile knife. The samples were placed into sterile bags and transported to the laboratory for analysis. The material was preserved at low temperature.

The algae were either determined directly from the sampled material or further cultivated as follows. A small proportion of each sample was mixed with 10 ml of distilled water. The suspension was mixed by a magnetic mixer for 15 minutes. Aliquots of 0.5 or 1 ml were spread in duplicate on agar solidified BBM medium (Bischoff & Bold 1963; Ettl & Gärtner 1995) and DY IV medium (Andersen et al. 1997). In addition, another proportion of the sample was merged to the liquid BBM medium. Cultures were sealed with parafilm and incubated at 20–25 °C under daylight conditions (the plates were placed beside a north facing window) until good growth had been obtained (3–6 weeks). Algal microcolonies were examined directly from agarized plates using an Olympus BX 51 microscope with Nomarski DIC optics and photographed using Olympus Camedia digital camera C-5050 Zoom. Standard cytological stains (Lugol's solution, methylene blue, acetocarmine, chloraliode solution) were used for visualisation of pyrenoid, cell wall structures or mucilage. For detailed investigation of some strains, the algal colonies were transferred to agarized BBM culture tubes and then cultivated at 18 °C, under an illumination of 20–30 μmol $m^{-2} \cdot s^{-1}$ and 16:8 h light-dark cycle. Identification was made on the basis of life history and morphological criteria using standard authoritative references (Printz 1964; Fott & Nováková 1969; Ettl 1978; Punčochářová & Kalina 1981; Komárek & Fott 1983; Krammer & Lange-Bertalot 1986, 1991; Ettl & Gärtner 1995; Hindák 1996; Lokhorst 1996; Andreeva 1998; Komárek & Anagnostidis 1998, 2005). A NMDS ordination analysis was performed using the statistical program PAST 1.74 (Hammer et al. 2001) to ordinate localities based on their algal composition.

RESULTS AND DISCUSSION

General conclusions

A total of 38 algal species representing 26 genera were recovered from four studied localities (Table 2.2.1). Five widespread taxa (diatoms *Diadesmis laevissima*, *Eunotia exigua* and *Eunotia fallax*; and green algae *Pseudococcomyxa simplex* and *Klebsormidium flaccidum*) were found in three localities. Generally, diatoms represented the most species-rich group of autotrophic organisms, in spite of their absence in Střezovská rokle (Figs. 2.2.1, 2.2.2). In all samples from České Švýcarsko, diatoms comprised at least 50% of all determined species. However, species-poor green algae were more abundant in samples CS1 and CS2. There, capsal green alga *Gloeocystis* sp. forms macroscopically visible

Table 2.2.1 Algal distribution in 4 investigated sampling sites (CS – National Park České Švýcarsko, SR – Střezovská rokle).

	Sampling site			
	CS1	CS2	CS3	SR
Cyanobacteria				
Aphanocapsa muscicola (Meneghini) Wille	×			
Aphanothece caldariorum Richter	×			
Chroococcus varius A. Braun in Rabenhorst		×		
Cyanothece aeruginosa (Nägeli) Komárek			×	
Pseudanabaena catenata Lauterborn			×	
Bacillariophyceae				
Achnanthes cf. *subatomoides* (Hustedt) Lange-Bertalot et Archibald			×	
Caloneis aerophila Bock	×	×		
Diadesmis contenta (Grunow ex Van Heurck) Mann	×			
Diadesmis laevissima (Cleve) Mann	×	×	×	
Eunotia exigua (Brébisson ex Kützing) Rabenhorst	×	×	×	
Eunotia fallax A. Cleve	×	×	×	
Eunotia glacialis Meister			×	
Eunotia meisterii Hustedt			×	
Eunotia paludosa Grunow	×			
Eunotia praerupta var. *bigibba* (Kützing) Grunow	×	×		
Frustulia saxonica Rabenhorst	×	×		
Microcostatus krasskei (Hustedt) Johansen et Sray		×	×	
Pinnularia borealis Ehrenberg		×		
Pinnularia pseudogibba K. Krammer		×	×	
Pinnularia schoenfelderi K. Krammer			×	
Pinnularia subcapitata W. Gregory			×	
Euglenophyta				
Euglena geniculata Dujardin	×			
Chlorophyceae				
Bracteacoccus sp.				×
Chlorococcum sp.			×	
Coelastrella striolata Chodat			×	
Diplosphaera chodatii Bialosuknia em. Vischer				×
Neodesmus sp.		×		
Scotiellopsis oocystiformis (J.W.G. Lund) Punc. et Kalina			×	
Trebouxiophyceae				
Apatococcus sp.			×	
Chlorella cf. *trebouxioides* Puncocharova	×			
Chlorella vulgaris Beijerinck				×
Microthamnion kuetzingianum Nägeli			×	
Pseudococcomyxa simplex (Mainx) Fott		×	×	×
Gloeocystis sp.	×	×		
Klebsormidiophyceae				
Klebsormidium crenulatum (Kützing) Lokhorst				×
Klebsormidium flaccidum (Kützing) Silva, Mattox et Blackwell		×	×	×
Klebsormidium mucosum Boye Petersen				×
Zygnematophyceae				
Cosmarium orthopunctulatum Schmidle			×	

algal mats on the surfaces of sandstone cliffs. Only in the brown-coloured algal mat (sample CS3) the diatoms constituted both the most abundant and the most species-rich component of the algal population. The above-mentioned differences can be explained by diverse physico-chemical characteristics, present at the sampling sites. While favourable light conditions of the sampling sites CS1 and CS2 give support to the massive development of green algae, the shadowed conditions of site CS3 prioritized diatoms. Although several green algal species were also determined in the CS3 sampling site, they did not dominate. Even more, green alga *Gloeocystis* sp., dominant in both others sampling sites in České Švýcarsko, was not found there.

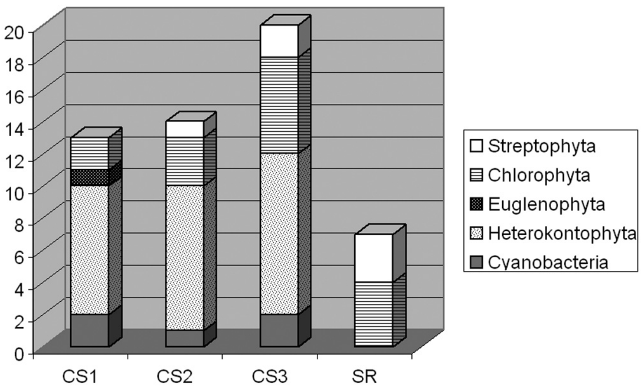

Fig. 2.2.1 Species richness expressed as the number of taxa found in each locality. Assignment of taxa to the four algal groups is displayed.

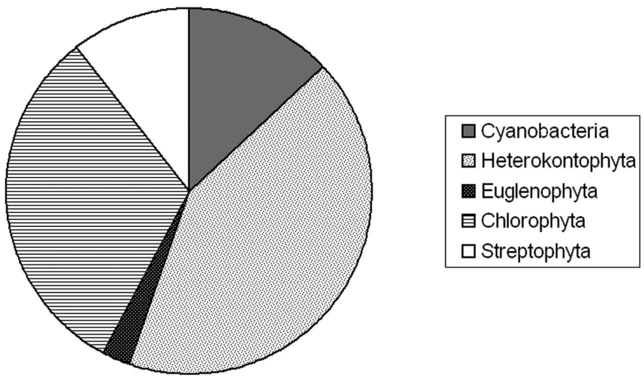

Fig. 2.2.2 Proportional occurrence of five algal groups, determined in all investigated localities.

Algal population in Střezovská rokle considerably differed from all the others. It differentiated in a small number of determined taxa as well as by an entire absence of some algal groups (e.g., cyanobacteria and diatoms). Formation of this unique algal population can be explained by unstable environmental conditions caused by continuous erosion of sediments from steep slopes.

In general, species composition among the localities substantially differed, as seen from the results of the NMDS ordination analysis (Fig. 2.2.3). The differences are distinct among the three sampling sites in the České Švýcarsko locality as well as between the two investigated localities (České

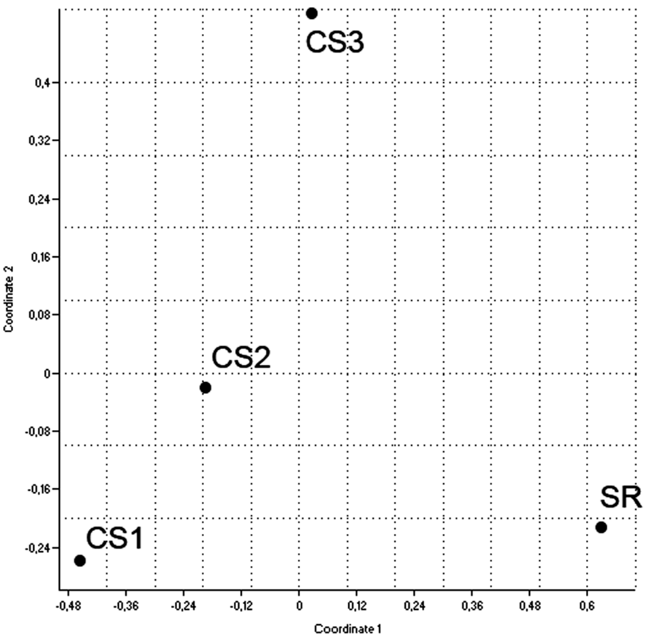

Fig. 2.2.3 The NMDS ordination diagram showing the position of samples in the range of the first two ordination axes (**CS** – National Park České Švýcarsko, **SR** – Střezovská rokle).

Švýcarsko and Střezovská rokle). In principle, the differences between the sampling sites CS1–CS3 and CS1–SR are comparable. In worldwide comparison to other natural biological soil crusts, the principal algal composition seems to be comparable, as cyanobacteria, diatoms and green algae represent the dominant algal groups occurring (e.g., Johansen et al. 1981; Ashley et al. 1985; Grondin & Johansen 1993; Evans & Johansen 1999). However, the species composition within these algal groups could considerably differ. For example, cyanobacterial genera *Nostoc* and *Microcoleus* are frequently recorded from desert soils, forming there the dominant component of total algal flora (Flechtner et al. 1998; Evans & Johansen 1999). In our samples, however, none of these genera occurred. Conversely, the dominant component of biological soil crusts in České Švýcarsko, green algal genus *Gloeocystis*, was never recorded for desert soil crusts.

Floristics

The morphology of selected widespreading species is illustrated in Fig. 2.2.4 (see Colour plates). The following pages provide detailed descriptions of several taxa found in the investigated localities.

Eunotia Ehrenberg (Figs. 2.2.4 f–i)

Diatom genus *Eunotia* is characterized by biraphid frustules, asymmetrical to the apical axis and symmetrical to the transapical axis. Dorsal margin is convex, smooth or undulate, ventral margin straight or concave. Raphe does not occupy much of the axial area, but it is restricted to the ends along the valve mantle and curving slightly or strongly onto the valve face at the apices. Terminal nodules are usually conspicuous. Frustules are box-like or rectangular in girdle view. Raphe branches are evident in girdle view.

A total of six species of *Eunotia* were found in the biological soil crusts developed on the surface of sandstone cliffs in České Švýcarsko. Two of them, *E. exigua* and *E. fallax*, were determined in all three sampling sites. Together with *Diadesmis laevissima*, they formed the most abundant diatom component of the whole algal population.

The genus is widespread. *Eunotia* species occur mainly epiphytic on the surface of filamentous algae. They prefer the acid habitats, occurring in the moorlands, peat-bogs, acidificated waters and aquatic or wet biotopes on the silicate substrata (Kramer & Lange-Bertalot 1991). Some of the determined species are often reported from the wet surfaces of sand-stone rocks (Alles et al. 1991). However, determination of *Eunotia glacialis* and *E. meisterii* represents the first record of these species in the aerophytic biotope (Ettl & Gärtner 1995).

Euglena geniculata Dujardin (Fig. 2.2.4 k)

Cells of *Euglena geniculata* frequently appeared in the sample CS1 (vertical sandstone cliff with green-coloured biological soil crust, České Švýcarsko). Cells were nearly cylindrical to bluntly spindle-shaped, with rounded anterior and pointed posterior end. The pellicle was very finely and closely striated, almost parallelly with the longitudinal axis of the cell. Band-shaped chloroplasts were arranged into two star-like groups. Paramylon bodies were numerous, short, rectangular or rod-shaped, located in the chloroplast centres. Cells exhibit slow euglenoid movement.

The species of *Euglena* are cosmopolitan, most commonly found in shallow and quiet waters, such as ponds and ditches. Some species are confined to low pH waters such as *Sphagnum* peat-bogs, others usually in water major organic pollution (Wołowski & Hindák 2003). *Euglena* is mostly a freshwater genus, only a few of species were recorded from aero-terrestrial biotopes (Ettl & Gärtner 1995). Just one of these species is *Euglena geniculata*, isolated e.g., from soil in England and Switzerland or from wet sandy shore in Czech Republic (Schlösser 1994).

Neodesmus sp. (Fig. 2.2.4 l)

Green alga, isolated form sampling site CS2, was characterized by fusiform to cylindrical cells, with acute or obtuse poles. Cell dimensions varied between 5–9 µm in length and 1.5–3 µm in width. Cell wall was smooth. The cells were uninucleate, possessing one parietal chloroplast with one pyrenoid. Asexual reproduction took place by autospores; 2 per sporangium.

The morphology of determined alga corresponds well to the description of green chlorophycean alga *Neodesmus*. Although *Neodesmus* represent the coenobial alga closely related to *Desmodesmus* and *Scenedesmus*, it can disintegrate into single cells if cultivated. Morphologically, the isolated strain resembles the species *Neodesmus pupukensis*, described from stagnant inshore waters of eutrophic freshwater Lake Pupuke, Auckland, New Zealand (Kalina & Punčochářová 1987). The second described species of the genus, *N. danubialis*, is recorded from the plankton of eutrophic freshwater, including rivers and fish ponds (Guiry & Guiry 2007).

Regarding the above-mentioned differences in ecology of both *Neodesmus* species and the isolated strain, we suppose that this strain very probably represents the new species of the genus *Neodesmus*, even more the new genus within Chlorophyceae. However, because of the scarcity of morphological features, taxonomic position of this strain could be resolved only with the appropriate aid of the molecular biology techniques.

Gloeocystis sp. (Fig. 2.2.4 m)

Algal genus *Gloeocystis* represents a widely distributed aerophytical organism, characterized by formation of distinct mucilaginous colonies. The colonies are microscopic with cells embedded in an irregular mucilaginous envelope and forming spherical to pyramidal to amorphous masses to about 55 µm diameter. Mucilaginous material is often distinctively lamellate around each cell or group of cells. Cells are spherical, with smooth cell walls, and uninucleate. Chloroplast is single and parietal, with single pyrenoid. Asexual reproduction takes place by autospores; 2–8(–16) per sporangium (Kostikov et al. 2002). *Gloeocystis* has a broad ecological range, occurring planktonic in freshwater or aerophytic on rocks or wood, terrestrial or associated with mosses.

Cells of *Gloeocystis* sp. constituted the dominant component of algal flora in two investigated sampling sites (SC1 and CS2). There, it forms macroscopically visible mucilaginous algal mats on the surfaces of sandstone cliffs. Cell dimensions, shape and autospore number correspond well to the description of *Gloeocystis vesiculosa*. However, taxonomic concepts vary among recent authors with *Gloeocystis* species and distinguishing features of *Gloeocystis* and various related genera, as well as for individual species, requiring re-evaluation (Kostikov et al. 2002; Wolf et al. 2003).

Cosmarium orthopunctulatum Schmidle

The rare desmid species *Cosmarium orthopunctulatum* was determined in the material sampled in the CS3 sampling site. Cells were medium-sized, a little longer than broad, with moderately deep median constriction. The sinus was distinctively open and acute-angled. Semicells were elliptic, with angles acutely rounded. Cell wall was ornamented by small granules, densely arranged in about 17 to 18 vertical series and 8 to 11 very indistinct horizontal series. In vertical view cells were subrhomboid with poles rounded. Cell dimensions varied between 29–36 µm in length and 26–39 µm in width, isthmus 9–12 µm.

The species *C. orthopunctulatum* was originally described from the Austrian Alps (Schmidle 1895). Afterwards, it was sporadically recorded from other places in the Alps (Migula 1907; Ducellier 1918; Messikommer 1942), Canada (Croasdale & Grönblad 1964) and Senegal (Compere 1991). Till this time, the total number of records does not exceed a ten. Therefore, determination of such rare species deserves consideration. Our finding represents not only the first record of *C. orthopunctulatum* in the Czech Republic, but also the first European record outside the Alps. In addition, determination of this species on wet sand-stone rocks further contributes to our knowledge about its ecological preferences.

CONCLUSIONS

Algal communities of natural biological soil crusts were investigated in two locations (National Park České Švýcarsko and Střezovská Rokle) in the Czech Republic. Microscopic examination of three samples in České Švýcarsko reveals similar community structures, always consisting of cyanobacteria, diatoms and green algae. The green algae that occur in crusts are morphologically simple unicells, packets of cells, or weak filaments, yet represent a diverse assemblage of taxa spanning the classes Chlorophyceae, Trebouxiophyceae, and Klebsormidiophyceae. In the two samples, green algae were more abundant than cyanobacteria and diatoms, with *Gloeocystis* sp. being the most common species. The dominance of certain algal groups or individual species can be affected by various physico-chemical characteristics such as light conditions, the influence of which was observed in this study. Algal population in Střezovská rokle was found considerably different, as compared to České Švýcarsko. The algal community consisted only of quickly growing R-strategist green algae, which we interpret as the impact of intense environmental disturbance caused by continuous erosion of sediments from steep slopes (Kuncová et al. 1999).